Appendix I

Entrance Skin Exposures

A. Entrance Skin Exposures for General Radiographic Equipment

1. Purpose: To ensure that entrance skin exposures (ESE) for standard radiographic techniques are within standards.

2. Regulations: Naval Environmental Health Center (NEHC) publishes national averages for the standard radiographic techniques. Joint Commission for Accreditation of Healthcare Organizations (JCAHO, 1994) requires ESE's, for techniques used most commonly, be evaluated on an annual basis.

3. Procedure

*a. **Manual Mode***

(1) In addition to the procedures outlined below, the following parameters must be known for each tube head to obtain specific organ doses:

(a) Source-to-skin distance
(b) Source-to-image receptor distance
(c) Technique factors for the selected projection
(d) HVL of the unit in question for the selected projection

(2) Set the clinically used SID. Center the ion chamber in the x-ray field at approximately 23 cm above the tabletop to minimize backscatter. Record the distance from the focal spot to the center of the ion chamber.

(3) Collimate the light field on the ion chamber using narrow beam geometry.

(4) Set the desired technique factors at the control panel.

(5) Expose the ion chamber and record the free-in-air exposure.

(6) Repeat as necessary for other commonly used projections and technique factors.

(7) Calculate the entrance skin exposure for each projection using the patient thickness guidelines in table 2 of HHS Publication (FDA) 89-8031 and the inverse square law. The inverse square calculation is as follows:

$$ESE = \left(\frac{x_1}{x_2}\right)^2 \times FIA$$

Where:

ESE = corrected x-ray beam intensity at the skin entrance
x_1 = focal spot to center of ion chamber distance
x_2 = distance from the focal spot to the surface of the skin ($x_2 = x_1$ - patient thickness)
FIA = Free in air exposure at the center of the ion chamber

(8) Interpretation of Results: Compare exposures received for standard techniques with the NEXT published national guidelines and rate as satisfactory or unsatisfactory. If exposures are not within recommended ranges, an evaluation of image quality should be conducted in consultation with the clinical staff. Factors such as: types of grids, types of screens, processor quality control, preference of clinical staff, and whether the x-ray unit meets all other performance test requirements should be evaluated. A qualified service engineer should be consulted for equipment adjustment.

(9) To determine tissue/organ doses for projections common in diagnostic radiology, use the ESE for each projection, the additional information in item 3.1 above and refer to HHS Publication (FDA) 89-8031.

(10) To estimate the dose to the embryo-fetus from radiographic examinations, refer to reference HHS Publication (FDA) 79-8079 and NCRP Report 54.

b. ***Automatic Exposure Control Mode***

(1) Measure and record the Half value layer of the X-ray beam.

(2) Set up X-ray unit for normal radiographs: chest, abdomen, and extremity.

(3) Place the patient phantom over the selected AEC detectors. (see figures I-1a and I-1b, shown for a chest unit)

(4) Place the ion chamber detector in the test stand's top position nearest the X-ray tube. Place the test stand flush on the table against the chest bucky. (Ensure that the detector does not cover the AEC sensor).

(5) With the ion chamber meter in pulse exposure mode; take an exposure at the kVp setting used for an average adult X-ray.

(6) Record the exposure on the data form along with the following distances:

a) Source to detector.
b) Source to film.

(7) Follow the steps in 3.(a)(7) through 3.(a)(10) above to calculate ESE, interpret results and to estimate organ dose/embryo-fetal doses.

B. Entrance Skin Exposures for Dental Intraoral Units

1. Procedure:

a. Place the probe about one inch from end of cone.

b. Use a technique commonly used on the machine to make an exposure. This is the ESE which should be recorded along with all settings used.

c. Record focal spot to chamber distance which represents the source to skin distance and approximates the source to image distance. Use the actual kVp as determined.

C. Entrance Skin Exposure Rates for Fluoroscopy Units

1. Procedure:

a. Refer to Appendix D, section A.2. for fluoroscopic entrance exposure rate measurement procedures. Tolerances are listed in Table D.3.

Note that 1100 alloy aluminum sheets are less suitable as a fluoroscopy ESE rate phantom than acrylic slabs since the aluminum represents significantly different equivalent patient thicknesses at different kVp values. Aluminum also does not provide the same amount of scatter as the thicker acrylic block. Experimental data has demonstrated up to 2X higher ESE rates using acrylic. However, not all evaluators will have acrylic phantoms in their equipment inventories. To maintain consistency, clearly identify the type of phantom used, record the testing conditions, and perform subsequent evaluations using the original phantom and conditions.

D. Digital/Mechanical Spot Film ESE

1. Introduction:

a. Fluoroscopy is routinely used as a localization mechanism for radiographic images that are analyzed at a later time. In many fluoroscopic examinations, the radiographic spot film exposure component can be substantial, especially if the use of contrast is involved. Therefore, accurate spot film entrance skin exposure (ESE) measurements are essential to maintaining a database for determining patient exposures.

b. Digital spot film exposure measurement assumes proper generator calibration and satisfactory operation of the imaging chain components. Image intensifier entrance exposure rate (μRfr^{-1}) must be properly set to the manufacturer's recommendation. For mechanical spot film devices, proper AEC subsystem operation is essential. For these reasons, spot film ESE testing is typically performed last during an acceptance inspection or annual performance evaluation.

2. Procedure:

a. Arrange the fluoroscopy unit and ion chamber in the configuration appropriate to the machine type; i.e. undertable tube, overtable tube, or C-arm. Appendix D, section A.2.c. applies. Ensure that if a grid is used in clinical studies, it is in the beam path during testing. If the system is equipped with a manual spot film device, place a loaded cassette in the II tower.

b. Place a 4 cm aluminum or 15 cm acrylic phantom in the beam in the same manner as for measuring entrance skin exposure rate. Ensure that the phantom sits between the ion chamber and the image intensifier tube.

c. If the unit provides specific spot film routines for different anatomical applications, program the system for non-contrast abdominal studies. If different dose levels are also provided, select a medium setting. If anatomical or dose programming are not provided, use the system's automatic brightness control (ABC) to determine the kVp to be used during testing. For manual only systems, program the unit for 80 kVp. Select an appropriate medium level current (e.g. 200 mA). Program a digital spot film system to operate at its minimum frame rate (1 frs^{-1} is most desirable). If appropriate, set the mechanical spot film device to terminate exposure using AEC.

d. Set the image intensifier to minimum size, collimating to the phantom dimensions if necessary. Fluoro the phantom briefly, allowing ABC to select an appropriate kVp. Several systems apply the ABC selected voltage directly to the spot film technique. For those that do not, the fluoro kVp serves as a useful baseline for manual spot film technique programming.

e. Irradiate the phantom and ion chamber using digital spot mode, recording the measured ESE and actual mAs. During acceptance, repeat for all available II sizes and dose settings, as applicable. During annual evaluations, test at the most commonly used dose setting using the largest II size.

f. For those units with an additional mechanical spot film device, measure ESE using the same kVp and mA as for the digital spot, but collimate the radiation field to match the largest II size. During acceptance, repeat using all available II sizes.

g. For pediatrics rooms, repeat the procedure using a 2 cm aluminum or 8 cm acrylic phantom thickness.

h. If spot films are made with and without a grid in the beam, repeat the procedure with the grid removed from the beam.

3. Interpretation of Results: Calculate an ESE rate as a function of mAs. Determine maximum, minimum, and average exposure/mAs. If current values differ from their acceptance or historical counterparts by more than ± 10 %, refer the system for adjustment by a qualified service engineer.

E. Linear Tomography

1. Purpose: Image mottle and resolution may be improved by increasing the photon fluence rate. This improvement in image quality is done at the expense of radiation dose to the patient. Tomography, especially thin section tomography (e.g., inner ear) may result in a total exposure between 12 R to 17 R for the series of films required. To minimize the dose to the patient, evaluation of entrance skin exposures (ESE) are performed for clinically used.

ENTRANCE SKIN EXPOSURE
(Data Sheet)

Location:_____ Date:_____

Room #:_____

Unit:
Make:_____Model:_____

Control Console Serial Number:_____

Tube:
Make:_____Model:_____

Serial #:_____ Configuration:_____

Detector:
Make:_____Model:_____

Serial #:_____ Calibration Date:_____

X-ray beam HVL (mm Al)	kVp	Exposure (mR)	Source to Detector Distance (inches)	Source to Film (inches)	Calculated ESE (mR)	Overall Evaluation Sat Unsat

Entrance Skin Exposure
Evaluation Performed by:_____